Fig. 1. *The results of torsion testing of the left femur after either 4 weeks of ambulation or 4 weeks of unloading in a spaceflight simulation model in rats fed either 0.3% (low) or 2% (high) levels of dietary salt. Panel A shows the results in the Dahl salt-sensitive rats with body weights averaging 238 grams (gr), and panel B shows the results in Dahl salt-resistant rats with body weights averaging 200 grams. The asterisk indicates statistically significant differences at $p < 0.05$. There do not appear to be differences in the response of femurs of salt-sensitive and salt-resistant rats to unloading.*

Effect of Age and Activity Level on Bone Mass and Distribution

Tammy Cleek, Robert Whalen

The objective of this study was to gain a better understanding of the relationship between age, activity level (as indicated by runners and non-runners), and site specific bone mass and long bone structural parameters related to long bone cross-sectional geometry. We hypothesized that bone mass measurements and long bone structural properties would be decreased with age but would be enhanced by a higher activity level.

Currently, the most widely used and accepted method of noninvasive skeletal assessment is dual energy x-ray absorptiometry (DXA) which measures regional and whole body changes in bone mineral content (BMC) and areal bone mineral density (BMD). However, whole bone stiffness and strength are not solely dependent on bone mass, but also upon its cross-sectional shape and distribution.

Bone densitometry has been previously used to obtain cross-sectional properties of bone in a single scan plane. In a new approach using three noncoplanar scans, this technique was extended to obtain the principal moments of inertia and orientations of the principal axes of each scan cross-section. This method has been validated using aluminum phantoms and cadaveric long bones. The method was used in this study to investigate structural properties in the long bones of the lower limb as a function of age and activity level in women.
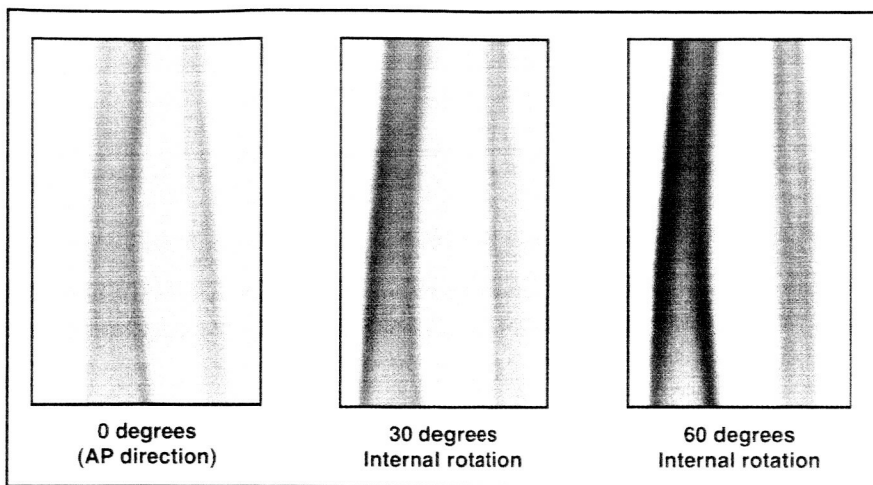
0 degrees
(AP direction)

30 degrees
Internal rotation

60 degrees
Internal rotation

Fig. 1. Typical scan images of the lower leg at three different angular orientations.

Twenty-six women were studied using the Hologic QDR-1000/W DXA bone densitometer. The women were recruited in two age groups, 25-35 (Y, n = 14) and 60+ (E, n = 12). Within the age groups were runners, considered high loaders (HL), and nonrunners, considered low loaders (LL). Three non-coplanar scans were taken of the middle third of the lower right leg of each subject. Between each scan, the right leg was rotated internally 30 degrees to obtain a different axial view of the same region of the lower leg. The first figure shows the resulting three bone images. Notice that in each of the three images the tibia and fibula are visibly separated. Thus, it is possible to process the bones independently.

Cross-sectional area (A), principal moments of inertia (Imax, Imin), and polar moment of inertia (J) were determined at each scan line for the tibia and fibula along the middle third of the lower leg. Tibia and fibula principal moments for one of the subjects is shown in Figure 2.

Bone mass is reflected by A, while Imax, Imin and J also account for bone mass distribution. Measurements were scaled by appropriate parameters to account for subject body size differences. Area was divided by normalized body weight (BW/BW_{mean}), and Imax, Imin and J were divided by normalized body weight
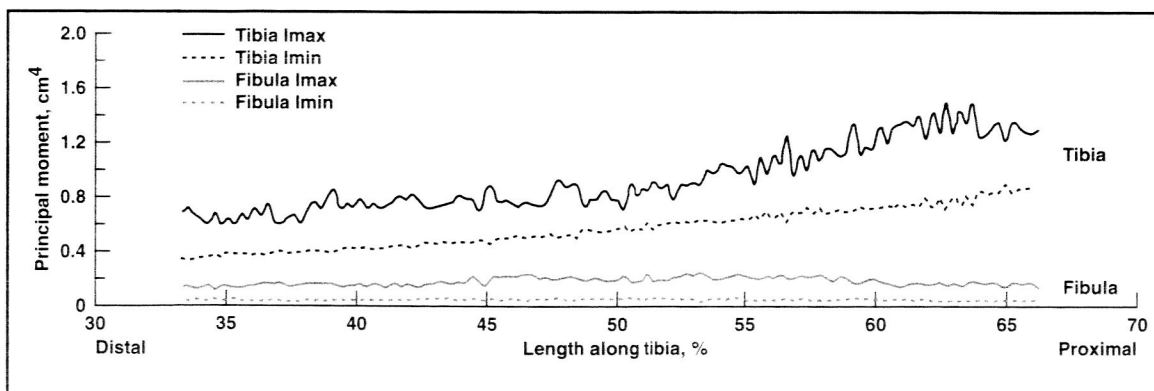

Fig. 2. Typical principal moment data for the tibial and fibular midshaft in a YLL subject.

(BW/BW$_{mean}$) and tibia length (l/l$_{mean}$), according to the axial force or moment generated about the tibial midshaft by the ground reaction force. Scaled values were averaged over the entire middle third section for each subject, and group means were calculated and are reported in the table.

In the tibia, the mean A*, Imax* and J* values were significantly higher in runners for both age groups. There was no dependence on age for any of the measurements. Interestingly, the fibula did not show corresponding changes. We postulate that high loads associated with running lead to increased bone structural parameters to support axial loads (A), bending (Imax), and torsion (J) in the tibia.

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TABLE 1. MEAN VALUES FOR TIBIA AND FIBULA

		Tibia				Fibula			
Group	n	A* (cm^2)	Imax*(cm^4)	Imin*(cm^4)	J* (cm^4)	A* (cm^2)	Imax*(cm^4)	Imin*(cm^4)	J* (cm^4)
EHL	5	[a]2.548	[a]1.764	0.763	[a]2.527	0.528	0.129	0.031	0.160
ELL	7	1.991	1.094	0.594	1.688	0.492	0.101	0.028	0.129
YHL	5	[a]2.556	[a]1.549	0.748	[a]2.297	0.550	0.117	0.023	0.140
YLL	9	2.004	1.113	0.593	1.706	0.523	0.135	0.026	0.163

*Indicates scaled values; [a]$P < 0.05$.

BIOASTRONAUTICS RESEARCH

NASA Virtual GloveboX (VGX): Advanced Astronaut Training and Simulation System for the International Space Station

Jeffrey D. Smith, Richard Boyle

In the coming years, the International Space Station (ISS) will provide a permanent microgravity laboratory for biological research in space. From this orbital laboratory, astronaut crews will carry out complex life science experiments designed to answer long-standing questions concerning life's ability to adapt and respond to the space environment. Many of these experiments will require the use of the Life Sciences Glovebox (LSG). Within the LSG, astronauts must manipulate scientific instruments, perform experimental assays, collect tissue specimens and record biological data—all under highly controlled conditions and within strict time constraints. These experiments often demand extensive training and knowledge of instrumentation, anatomy, and specific scientific objectives. Furthermore, astronauts must remain highly proficient but, due to scheduling constraints, they can receive only limited Earth-based training with LSG mock-ups and real experiment specimens.